

RELATIVE EFFECTIVENESS OF COLLABORATIVE AND ANONYMOUS PEER ASSESSMENT TECHNIQUES ON STUDENTS' ACHIEVEMENT IN ECOLOGICAL CONCEPTS

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Abstract. *In many developing countries where conventional assessment techniques remain prevalent in schools, limited research exists on the impact of various forms of peer assessment, particularly collaborative and anonymous techniques, on students' achievement in demanding science subjects such as ecological concepts. This study examined the relative effectiveness of collaborative and anonymous peer assessment techniques on students' achievement in ecological concepts, as well as the influence of gender on achievement outcomes. A quasi-experimental, pre-test–post-test, non-equivalent control group design was employed, involving 137 Biology students. Data were gathered using a pre-test and post-test achievement measure administered to all participants. The findings revealed that the collaborative peer assessment technique (CPAT) was significantly more effective in enhancing students' achievement in ecological concepts than both the anonymous peer assessment technique (APAT) and the conventional assessment technique (CAT). The anonymous peer assessment technique also produced a statistically significant improvement in students' achievement when compared with the CAT. Furthermore, no significant difference was observed between the achievement of male and female students when taught ecological concepts using either CPAT or APAT.*

Keywords: *achievement in ecological concepts, collaborative peer assessment, conventional assessment technique, anonymous peer assessment, experimental study*

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Introduction

Biology is a fundamental discipline that has played a vital role in helping individuals and societies address numerous challenges related to the environment, nutrition, and health. It is integral to all aspects of human life; consequently, the biology curriculum encompasses topics such as ecology, microorganisms and health, nutrition, association, ecosystem functioning, and genetics, among others. However, the persistently poor performance of students in biology and other science subjects has become a global concern, as academic achievement in science directly influences students' career choices and contributes to national development (Bichi et al., 2019).

To ensure meaningful learning outcomes, the teaching and learning of biology must adopt appropriate assessment techniques that assist students in identifying their areas of weakness, overcoming learning obstacles, developing a positive attitude, and addressing challenges inherent in the subject matter. According to Igbojinwaekwu and Dorgu (2019) and Isma'il and Matazu (2024), biology topics commonly perceived as difficult by students include the nutrient cycle in nature, neurological coordination, association, sensory receptors and organs, the respiratory system, ecology, supporting tissues and systems, pests and diseases of crops, variation (adaptation for survival and evolution), and genetics. Determining the factors contributing to the difficulty of these topics, and their influence on students' achievement, has remained a key focus of biology education research. Extant empirical evidence has demonstrated that several interrelated factors impact students' academic achievement. Some of these factors include gender and teaching method (Jegade & Awodum, 2015; Nwankwo et al., 2024), students' perception of their teacher and classroom dynamics (Almasri et al., 2021; Shuaibu & Ishak, 2020), students' past academic performance (Rybczynski & Schussler, 2013), and teacher characteristics (Mokoro et al., 2014). Considering these factors, efforts to improve students' academic achievement in Biology, among other



learning outcomes, have seen researchers like Danjuma et al. (2021) and Omaka and Osuafor (2020) advocate for the use of a peer assessment teaching strategy.

Peer assessment is often wrongly interpreted as a grading platform. However, it offers much more than that as it provides the platform for students to actively participate in the teaching and learning process. It also allows students to meaningfully interact with lesson content, participate in the evaluation process, and acquire critical thinking and creativity skills in the process (Danjuma et al., 2021; Double et al., 2020). In practice, peer assessment allows learners to review their work, assess others', and make adjustments aimed at improving understanding. Mphahlele (2022) found that peer assessment also facilitates reflective learning by allowing students to compare performance, grasp standard levels, and identify areas for improvement. Strijbos and Sluijsmans (2010), as well as Topping (2010), listed some forms of peer assessment: formative, summative, collaborative, and anonymous. This study centres on collaborative and anonymous formats, both of which enhance peer learning in a way that alleviates stress and facilitates natural interaction and feedback (Gennip et al., 2010). This aligns with Vygotsky's (1978) sociocultural theory, which emphasises the need for active learners' participation through engagement, reflection, and interaction from which knowledge is acquired. In the context of the present study, peer assessment is a vital technique to enhance students' deeper understanding of complex scientific concepts.

Collaborative peer assessment, in particular, creates a deeper understanding by encouraging students to evaluate their work. It also offers useful insights into other students' development. It allows students to demonstrate adequate metacognition, making sense of knowledge, and improving their achievement (Amhag, 2013; Ibarra-Saiz et al., 2020; Shen et al., 2020). For Topping (2010) and William (2011), in a collaborative classroom culture, students recognise that they have learning responsibilities and distinct learning cognitions aimed at providing constructive, courteous, and nonjudgmental feedback for positive learning outcomes. The two goals of collaborative peer assessment are formative and diagnostic evaluation (Mphahlele, 2024), while diagnostic assessments assist educators and students in identifying some of the students' areas of weakness and learning challenges, formative evaluations are used to monitor students' learning development while they are receiving lessons. In contrast to the conventional assessment, collaborative peer assessment encourages student autonomy and cultivates skills essential for lifelong learning (Olutola & Owolabi, 2019).

On the other hand, anonymous peer assessment provides a different type of benefit. As explained by Falchikov (2005) and Strijbos and Sluijsmans (2010), it offers constructive criticism regarding a work through appropriate evaluation without knowing who owns it, thereby ensuring honest feedback and fair judgment. Studies show unfair grading happens as a result of ethnicity, educational deficiencies, physical appearance, and past performance (Batey, 2018; Chan, 2025; Chowdhury et al., 2020; Malouff & Thorsteinsson, 2016). Anonymity for assessors improves fairness and helps with good criticism. The quality of comments changes depending on whether students know each other's identities (Liu & Carless, 2006; Yu & Sung, 2015). A study by Rotsaert et al. (2018) found that anonymity facilitates a reduction of anxiety levels while stimulating honest participation. Although it might restrict back-and-forth discussion, teachers can create systems that retain anonymity while also tracking personal contributions and needs for learning.

Collaborative peer assessment is also seen as an innovative way to develop higher-order thinking skills and monitor student progress (Amhag, 2013). Rico-Juan et al. (2022) found that multiple rounds of peer evaluation improved both learning and grading accuracy. However, research on anonymous peer assessment presents more mixed results. For example, while Kiekkas et al. (2016) reported benefits, others like Batten et al. (2013) found no notable impact on grading reliability, and Pitt and Winstone (2018) noted potential drawbacks, including weakened teacher-student rapport. Similarly, Sharp and Zhu (2020) observed inconsistent effects of anonymity in reducing bias, although Shaheen et al. (2021) and Rotsaert et al. (2018) showed it could improve response rates and reduce anxiety.

To ensure fairness in group evaluations, Ma et al. (2020) recommend combining anonymous feedback with random group formation. In sustainability education, Ostuzzi and Hoveskog (2020) found peer feedback to be a valuable strategy, while Flournoy and Bauman (2021) and Kennedy-Clark et al. (2017) recommended integrating self- and peer-assessment tools for more equitable task sharing. While the educational benefits of peer assessment have been studied across various domains, including its effects on academic outcomes (Rico-Juan et al., 2022), critical thinking (Amhag, 2013), and feedback quality (Kahiigi et al., 2012), its use in teaching ecological concepts remains underexplored, especially within Nigerian secondary schools.



Considering that there is a cultural and social climate in Nigerian classrooms in which gender biases occur in science teaching (Ezeudu et al., 2019), it is also examined in this study whether gender will contribute to influences on learning achievements for learners who are taught with these peer assessment methodologies. Past literature has been inconsistent: some writers report no gender-associated variation (Ocampo et al., 2022), while a different set (Omaka & Osuafor, 2020) assert that boys may be more effective in peer-assessment situations. Each set of conflicting findings provides a rationale for further study.

Despite growing interest in peer assessment globally, conventional assessment still dominates science education in Nigeria and other developing regions. Exploring alternatives like collaborative and anonymous peer assessment could open new paths toward more inclusive and effective teaching strategies. These conventional approaches often fail to foster active student engagement. While existing research affirms the benefits of peer assessment, there remains limited evidence concerning its application to the teaching of ecological concepts in Nigerian secondary schools. Moreover, the moderating influence of gender has not been conclusively established, nor has the relative efficacy of collaborative and anonymous peer assessment been sufficiently explored in this context. To close this gap, and develop evidence-based teaching strategies that can improve students' achievement, promote inclusivity in science classrooms, and advance gender parity in science education, this study looks at how students in Anambra State, Nigeria, perform on collaborative and anonymous peer assessment methods in relation to ecological concepts, as well as whether gender has a significant impact on these results. These research questions guided the study:

RQ₁: What is the relative effectiveness of collaborative peer assessment, anonymous peer assessment, and conventional assessment techniques on students' mean achievement scores in ecological concepts?

RQ₂: What is the effectiveness of collaborative and anonymous peer assessment techniques on male and female students' mean achievement scores in ecological concepts?

Research Methodology

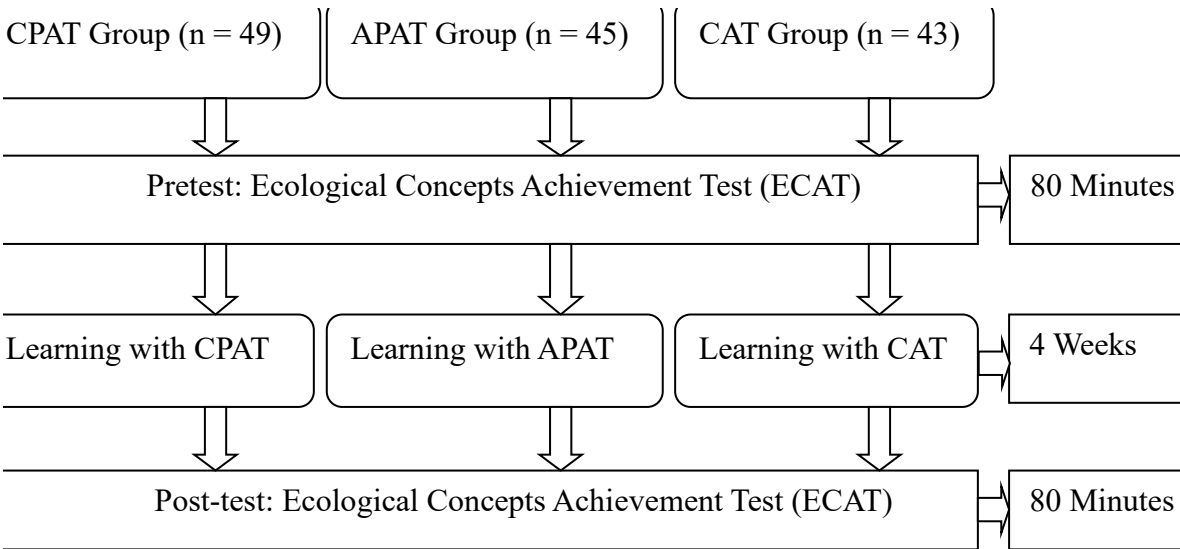
General Background

This study adopted a quasi-experimental research design, specifically, the pre-test and post-test non-equivalent control group design. This approach involved conducting assessments both before and after an educational intervention across three student groups: two experimental groups and one control group (Creswell & Creswell, 2018). The design was appropriate for the study, specifically given that the sample comprised intact classes, and it was impossible to achieve random assignment. The study aimed to explore how students' academic achievement in ecological concepts was affected by three different assessment techniques—Collaborative Peer Assessment Technique (CPAT), Anonymous Peer Assessment Technique (APAT), and Conventional Assessment Technique (CAT). Moreover, it attempted to identify if gender was also a significant factor in determining the result of learning. Based on Vygotsky's (1978) constructivist theory of learning, the study focused on students' best mode of acquiring knowledge, being active participation and peer- and teacher-related social interactions in the classroom. As per theory, meaningful aspects of learning take place when students collectively interact with peers as well as teachers in a way that they develop knowledge based on dialogue as well as collective experiences.

The research process was implemented in several phases. First, all three groups completed a pre-test to assess their initial understanding of ecological concepts. Following this, each group received teaching based on one of the three assessment techniques. After the intervention period, the same test was re-administered as a post-test to evaluate any learning gains. To analyse the effectiveness of the interventions, the researchers compared students' performance using mean scores, standard deviations, and inferential statistics, including ANCOVA and the Scheffé post-hoc test, with a significance level set at .05. The study took place in three co-educational secondary schools located in Awka South Local Government Area, Anambra State, Nigeria. The experimental phase was carried out between November and December 2024, aligning with the first term of the 2024/2025 academic year.



Figure 1
Experimental Steps



The study was conducted in three of the nineteen public secondary schools in Awka South Local Government Area, Anambra State, Nigeria. A total of 1,043 Senior Secondary Two (SS2) students formed the population. Since gender was a key variable in the research, three co-educational schools were purposefully selected to ensure representation. From each school, one intact SS2 class was randomly assigned to one of the three groups. This yielded a final sample size of 137 Biology students. To determine the adequacy of this sample, the researchers conducted an a priori power analysis using G*Power version 3.1 (Faul et al., 2009). The goal was to identify the minimum number of participants required for a study involving three independent groups and one covariate (pre-test scores), analysed using ANCOVA within the fixed effects, main effects, and interactions model under the *F*-test family. Key parameters for the power analysis included a significance level (α) of .05, a statistical power of .80, and a medium effect size ($f = .30$), a benchmark commonly recommended by Cohen (1988). The setup specified two numerator degrees of freedom and one covariate. Based on these inputs, the analysis revealed that a minimum sample of 111 participants would be required to detect meaningful differences among the groups. Therefore, the actual sample size of 137 was considered statistically significant. Therefore, the sample size employed was deemed appropriate. The Conventional Assessment Technique (CAT) was used as the control group, while the experimental groups were the Anonymous Peer Assessment Technique (APAT) and the Collaborative Peer Assessment Technique (CPAT). There were 49 students (20 males and 29 females) in the CPAT group, 45 students (22 males and 23 females) in the APAT group, and 43 students (23 males and 20 females) in the CAT group.

Procedures

The Research Ethics Committee of the Department of Science Education at Nnamdi Azikiwe University in Awka, Anambra State, Nigeria, granted ethical permission (REC/DSE/NAU/24/0089). After obtaining the consent of the principals of the three selected secondary schools, the researchers met with the students and regular Biology teachers. The students were provided with identification numbers, as they were guaranteed the study's confidentiality and the liberty to opt out of the study at any moment. The three Biology teachers, each with 10 years of experience, received eight days of training (three days for each teacher) on the fundamentals and procedures of conventional assessment, anonymous peer assessment, and collaborative peer assessment. Using the lesson plan, the researchers showed the teachers the study's methodology and pattern on the first day. Following this session, the researchers observed and made any required modifications while the teachers studied the lesson plan on the second day and practised everything they had learnt on the third day. A pre-test was given by the teachers and collected immediately before the commencement of the treatment. The data were recorded and documented by the researchers. The groups received lessons on ecological concepts, including tolerance, association, and the nutrient cycle in nature. During each lesson, the teachers gave the students exercises or class assignments,



divided them into groups of three to four students so they could evaluate each other's work, and used discussion to offer suggestions and feedback. Meanwhile, the students responsible for the work ensured that the necessary revisions were made. In the anonymous peer assessment class, the Biology teacher collected the students' work, maintained anonymity by distributing the submissions and work to the students at random after erasing the students' identities, and ensured that they did not assess themselves. The students in the control group were exposed to the conventional assessment technique, in which the teachers were responsible for the teaching and assessment procedures. The impacted students then gave feedback and made adjustments. Following the four-week duration of treatment, the reshuffled ECAT was administered as a post-test in the fifth week. For analysis, the researchers marked and recorded the data. Using their identification numbers, the post-test results were logged for each student according to their groupings.

Instrument

The instrument used for data collection was titled the Ecological Concepts Achievement Test (ECAT), adapted from the West African Examinations Council's (WAEC) (2000–2024) Biology past examination papers. It was structured by the researchers and consisted of 50 multiple-choice items. The topics of the test were based on ecological concepts: nutrient cycle in nature (48%), association (32%), and tolerance (20%). To ensure content validity, a test blueprint was created that showed how the test items were distributed across the topics. Bloom's taxonomy of cognitive domains was used, which included remembering (32%), understanding (30%), applying (12%), analysing (8%), evaluating (4%), and creating (14%). Three specialists from Nnamdi Azikiwe University's Faculty of Education, Department of Science Education (two from the Biology unit and one from the Measurement and Evaluation unit) validated the instrument, lesson plan, test blueprint, research questions, and hypotheses. The study utilised thirty Senior Secondary Two Biology students from a different school, which was not part of the study, for the trial testing of the instrument. Using the Kuder-Richardson Formula 20 (KR-20), the internal consistency of the ECAT was assessed, yielding a coefficient of .84.

Data Analysis

The mean and standard deviation were utilised to answer the study questions, and the hypotheses were tested at the .05 level of significance using Analysis of Covariance (ANCOVA). Because it allows the pre-test to be used as a covariate with the post-test, ANCOVA was employed. Additionally, at the .05 level of significance, the direction of the difference between the means of the three groups was ascertained using the Scheffé Post Hoc Multiple Comparison test. Using Cohen's (1988) d-value classification, the size of the treatment's effect on achievement was assessed as follows: > 1 (very large), .80 (large), .50 (moderate), and .20 (small). Furthermore, before conducting the ANCOVA, the researchers ensured that the necessary assumptions were met. Levene's test was used to confirm that the three groups' scores were homogeneous for the pre-test ($F = .485, p = .617 > .05$) and post-test ($F = .602, p = .549 > .05$). Also, to ascertain the normality of the data, the Shapiro–Wilk test was employed for the pre-test (CPAT: $W = .969, p = .216 > .05$; APAT: $W = .965, p = .196 > .05$; CAT: $W = .979, p = .617 > .05$) and post-test (CPAT: $W = .969, p = .230 > .05$; APAT: $W = .955, p = .077 > .05$; CAT: $W = .961, p = .153 > .05$); hence, the data are normally distributed.

Research Results

Although students exposed to the conventional assessment technique had pre-test mean achievement scores of 28.60 and post-test mean achievement scores of 50.65, with gained mean achievement scores of 22.05, Table 1 also shows that students taught ecological concepts using the collaborative peer assessment technique had pre-test mean achievement scores of 31.84 and post-test mean achievement scores of 76.51, with gained mean achievement scores of 44.67. Those taught using the anonymous peer assessment technique had pre-test mean achievement scores of 30.67 and post-test mean achievement scores of 60.98, with gained mean achievement scores of 30.31. When compared to students who were taught using anonymous (4.94) and collaborative (5.24) peer assessment approaches, the post-test score variation for the conventional assessment technique was low (4.29). The difference in the groups' mean achievement scores indicates that students in the CPAT group performed better than those in the APAT and CAT groups. The following hypothesis was tested to verify the significance of these differences.



Table 1*Mean and Standard Deviation of Pretest and Post-test Achievement Scores of Students Taught Ecological Concepts Using the Three Groups*

Technique	<i>n</i>	Pretest		Posttest		\bar{X} Gain
		\bar{X}	SD	\bar{X}	SD	
CPAT	49	31.84	7.85	76.51	5.24	44.67
APAT	45	30.67	7.25	60.98	4.94	30.31
CAT	43	28.60	8.09	50.65	4.29	22.05

The mean achievement scores of students in ecological concepts, when taught via CPAT, APAT, and CAT, differ significantly, as shown in Table 2 ($F(1, 133) = 318.740, p < .001, \eta_p^2 = .827$). As a result, when teaching ecological concepts using three distinct techniques, mean achievement scores differ significantly. The effect size is large at 82.7%, as indicated by the partial eta squared value of .827 that was found. As a result, the methods are responsible for 82.7% of the difference in students' ecological concepts achievement scores. Table 3 shows the results of a post hoc analysis utilising Scheffé Post Hoc analysis to ascertain the order of the significance difference.

Table 2*ANCOVA result of Ecological Concepts Achievement Between the three Groups*

Source	SS	df	MS	F	p	η_p^2
Corrected Model	15705.229a	3	5235.076	222.229	<.001	.834
Intercept	30222.324	1	30222.324	1282.940	<.001	.906
Pretest	31.898	1	31.898	1.354	.247	.010
Techniques	15017.191	2	7508.596	318.740	<.001	.827
Error	3133.092	133	23.557			
Total	567643.000	137				
Corrected Total	18838.321	136				

Table 3*Scheffe PostHoc Analysis on Significance of Mean Difference in Achievement Between Groups*

(I) Techniques	(J) Techniques	Multiple Comparisons				
		MD (I-J)	SE	<i>p</i>	95% CI	
					LB	UB
CPAT	APAT	15.5324*	1.00344	<.001	13.0485	18.0163
	CAT	25.8590*	1.01554	<.001	23.3452	28.3729
APAT	CPAT	-15.5324*	1.00344	<.001	-18.0163	-13.0485
	CAT	10.3266*	1.03642	<.001	7.7611	12.8921
CAT	CPAT	-25.8590*	1.01554	<.001	-28.3729	-23.3452
	APAT	-10.3266*	1.03642	<.001	-12.8921	-7.7611

The mean achievement scores of students taught ecological concepts using the three groups differed significantly, according to the Scheffé post hoc analysis results, which are displayed in Table 3. According to the results, students in CPAT performed noticeably better than those in APAT and CAT, while students in APAT performed better than those in CAT. Consequently, the Collaborative Peer Assessment Technique has the greatest impact, followed by the Anonymous Peer Assessment Technique, and then the Conventional Assessment Technique.

Table 4

Mean and Standard Deviation of Pretest and Posttest of Achievement Scores of Male and Female Students Taught Ecological Concepts Using CPAT and APAT

Technique	Gender	n	Pretest		Posttest		\bar{X} Gain
			\bar{X}	SD	\bar{X}	SD	
CPAT	Male	20	33.80	8.18	77.15	4.87	43.35
	Female	29	30.48	7.46	76.07	5.52	45.59
APAT	Male	22	30.64	6.91	60.77	4.28	30.13
	Female	23	30.70	7.71	61.17	5.60	30.47

In contrast to their female counterparts, who had pre-test mean achievement scores of 30.48 and post-test mean achievement scores of 76.07, with gained mean achievement scores of 45.59, male students who were taught ecological concepts using the Collaborative Peer Assessment Technique had pre-test mean achievement scores of 33.80 and post-test mean achievement scores of 77.15, with gained mean achievement scores of 43.35, according to Table 4. In the post-test mean score, the adoption of the Collaborative Peer Assessment Technique decreased the score variation among male students ($SD = 4.87$) more than that of female students ($SD = 5.52$). Additionally, Table 4 demonstrates that male students who were taught ecological concepts using an Anonymous Peer Assessment Technique had mean achievement scores of 30.64 and 60.77 on the pre-test and post-test, respectively, with a gained mean achievement score of 30.13. On the other hand, female students had mean achievement scores of 30.70 and 61.17 on the pre-test and post-test, respectively, with a gained mean achievement score of 30.47. In the post-test mean score, the Anonymous Peer Assessment Technique decreased the score variation among male students ($SD = 4.28$) more than that of female students ($SD = 5.60$). When ecological concepts are taught utilising collaborative and anonymous peer assessment techniques, the mean achievement score of the female students tends to be slightly higher.

Table 5

ANCOVA Result of Male and Female Students' Ecological Concepts Achievement Between CPAT and APAT Groups

Source	SS	df	MS	F	p	η^2_p
Corrected Model	5732.476a	4	1433.119	55.025	<.001	.712
Intercept	21145.791	1	21145.791	811.895	<.001	.901
Pretest	57.578	1	57.578	2.211	.141	.024
Techniques	5473.857	1	5473.857	210.169	<.001	.703
Gender	.640	1	.640	.025	.876	<.001
Techniques * Gender	7.204	1	7.204	.277	.600	.003
Error	2318.002	89	26.045			
Total	456551.000	94				
Corrected Total	8050.479	93				

According to Table 5, there is no significant main effect between the treatments (CPAT & APAT) and the ecological concepts achievement scores of male and female students ($F(1,89) = .025, p = .876 > .05, \eta_p^2 = .001$). Therefore, when ecological concepts are taught utilising collaborative and anonymous peer assessment approaches, there is no significant difference in the mean achievement scores of male and female students. The effect size, which measures the difference between male and female students' achievement in ecological concepts, is negligible ($< .001$).

Discussion

Research question one's findings demonstrated that collaborative peer assessment techniques are significantly more effective than both anonymous and conventional assessment techniques in enhancing students' achievement in ecological concepts. Additionally, students exposed to the Anonymous Peer Assessment Technique performed significantly better than those exposed to the Conventional Assessment Technique. Accordingly, the post hoc analysis revealed that the order of the significant difference between the techniques is CPAT, followed by APAT and then CAT.

This suggests the importance of peer assessment as seen in CPAT and APAT in improving students' achievement relative to CAT. One likely explanation is that these techniques actively involve students in the learning process, encouraging interaction and participation during peer evaluation activities. Through the act of giving and receiving feedback, students gain a deeper understanding of the learning objectives and expectations. This aligns with Vygotsky's sociocultural theory, which emphasises the importance of active classroom engagement and social interaction in constructing knowledge (Vygotsky, 1978). CPAT creates a dynamic learning environment, leveraging dialogue, reflection, and feedback to enhance understanding and develop critical thinking skills.

Previous studies also validate these findings. For instance, Shen et al. (2020) and Ibarra-Saiz et al. (2020) have demonstrated that peer assessment can significantly improve student achievement, learning abilities, and identification of their areas of weakness. Collaborative feedback dialogues supported by realistic assessment promote general skills and critical thinking, which in turn improve learning and, ultimately, achievement (Koh et al., 2019; Sahera et al., 2022). Studies by Amhag (2013) and Rico-Juan et al. (2022) also reported that collaborative peer assessment enhances students' development of higher learning skills and improves their performance in various academic disciplines, distance education, and higher education, as well as improving score accuracy. Furthermore, it concurs with findings by Li et al. (2008), who noted that students felt less peer pressure when they were peer-assessed anonymously and were more inclined to participate fully, a factor that tends to produce good academic achievements. The findings contradict aspects of Li and Gao (2015), who opined that while the participation of the peer assessment model immediately boosted low and average students' performance, it had less impact on high achievers.

The results for the second research question showed that if ecological concepts are learned under conditions of peer assessment that are both collaborative and anonymous, then there is no significant gender difference in students' mean achievement scores. The non-occurrence of a significant gender difference in students' achievement in ecological concepts might be a result of the inclusiveness of the two peer assessment approaches that might have facilitated both female and male students to attain a very high level of success in the concepts.

It is also possible that both genders actively took part in peer assessment exercises that would have equally aided their academic advancements. Their combined participation, interactions, and involvement appear to enhance their comprehension of ecological principles and enhance their cognitive capacity. This reveals that the learning benefit of peer assessment does not become constrained by gender. Multiple studies also proved that peer assessment enables peer collaboration, along with improving performance, interest, and interpersonal skill development of students regardless of gender. Peer assessment methodologies are highly valued as effective tools in raising higher-order thinking ability along with active learning. In prompting students to review their work as much as that of fellow students, these tools foster critical thinking ability along with problem-solving while also encouraging students to improve work quality with timely constructive feedback (Kahiigi et al., 2012; Ocampo et al., 2022). All these findings complement with regards to the outcome of the present study that showed both the Collaborative Peer Assessment Technique (CPAT) as much as the Anonymous Peer Assessment Technique (APAT) appreciably enhancing student achievement of ecological concepts. Notably, positive impact was experienced in both genders of students, showcasing that both techniques provide gender-inclusive, significant teaching opportunities that foster effective problem-solving ability.

Conclusions and Implications

Based on study findings, it is clear that the Collaborative Peer Assessment Technique (CPAT) is considerably more effective for enhancing students' achievement in ecological concepts than both the Anonymous Peer Assessment Technique (APAT) and Conventional Assessment Technique (CAT). The study indicates a distinct rank in effectiveness: CPAT > APAT > CAT. This underscores the value of student collaboration, active participation, genuine assessment practice, and meaningful peer feedback for cultivating deeper conceptual understanding and academic achievement. Notably, no significant gender disparities in CPAT and APAT effectiveness were obtained from this study. This indicates the gender-inclusivity of these peer assessment measures, whose equitable learning opportunities benefit both genders.

Although peer assessment has been studied comprehensively, our study addresses a gap by comparatively validating three different measures of assessment in a straightforward manner. Also, the study brings new insights by focusing on ecological concepts, an important understudied concept in science education, with poor achievement among students. The finding that collaborative and anonymous peer assessment techniques are equally effective for both genders also adds a novel perspective to the discourse on gender equity in education. Given that many educational systems around the world deal with issues like gender inequality, low science achievement, and inadequate resources, the study offered evidence-based insights that are applicable outside of the Nigerian context. In keeping with the global pedagogical shift towards learner-centred and constructivist approaches in schools, it also offers low-cost strategies for inclusive science classrooms, active engagement, and participation. The findings of the study have several educational implications for science education. It calls for active student involvement in the learning processes, as demonstrated by the effectiveness of CPAT, which suggests that students take ownership of their academic progress through meaningful interactions, deep understanding, and enhanced feedback. These processes, as observed, not only improve achievement in ecological concepts but also promote communication, critical thinking, motivation, and interpersonal skills among students.

It also provides compelling evidence for teachers to reconsider the continuous use of CAT and embrace CPAT and APAT to encourage honest feedback and create a collaborative, inclusive learning environment where both male and female students thrive equally, especially in culturally dynamic countries around the world. When this is integrated into existing classroom practices, it helps to reduce teachers' workload over time, as it becomes part of normal learning activities. The findings highlight the need for curriculum planners and policymakers to integrate structured peer assessment frameworks into teacher education curricula as well as science curricula for the overall achievement of learning objectives. This will help reduce future training burdens and enhance the successful application of the techniques in underfunded schools worldwide. This aligns with the broader objectives of promoting competency-driven education, active learning, and equity in STEM educational attainment. Hence, future research can explore discipline-specific applications of peer assessment, how it can serve as a tool for inclusive pedagogy across diverse learning environments, and the possible integration of digital tools (technology) to support anonymous peer assessment, which will reduce peer pressure and encourage more honest and constructive evaluations. Moreover, although the influence of gender on students' achievement was examined, the researchers recommend that a qualitative study on students' perceptions of the effectiveness of CPAT and APAT be conducted to provide deeper insight into the findings of the study.

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Declaration of Interest

The authors declare no competing interest.

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